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Population Characteristics and Movement of Roundtail Chub in the Lower Salt and Verde Rivers, Arizona

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POPULATION CHARACTERISTICS AND MOVEMENT OF ROUNDTAIL CHUB IN THE LOWER SALT AND VERDE RIVERS, ARIZONA

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ACKNOWLEDGEMENTS

This report is the result of information gathered in cooperation with the United States Bureau of Reclamation (USBR) and the Arizona Game and Fish Department (AGFD) to study the native and nonnative fishes of the lower Salt and Verde rivers. Funding was provided by the USBR. We express gratitude to everyone who helped in our PIT tagging efforts from AGFD, U.S. Fish and Wildlife Service, and USBR. We also thank Diana Rogers (AGFD) for her assistance with radio tracking fish. Mariann Kolozar provided radiotelemetry technical support. A special thank you to Steve Durand of Saguaro Lake Ranch who provided camping facilities and support throughout the project.

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We thank Rob Clarkson, Scott Gurtin, Pam Sponholtz, and Ross Timmons for their valuable comments and suggestions for this report.

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Population Characteristics and Movement of Roundtail Chub in the Lower Salt and Verde Rivers, Arizona

Scott D. Bryan and Anthony T. Robinson

Abstract: During April 1999 - August 2000, we PIT tagged 877 roundtail chub in the lower Salt and Verde rivers to aid in determining their local life history; including habitat use, population characteristics, and general movement. In addition, we radio-tagged 20 roundtail chub in the two rivers in 2000 and tracked their movement over a five month period (March - July). Habitat use was consistent with existing literature, with roundtail chub inhabiting pool-glide complexes that were adjacent to swift moving riffles. Over 6,400 roundtail chub (95% CI = 5,048-8,397) were estimated to occupy the lower Salt and Verde rivers from mark-recapture data. Roundtail chub were larger in size than found in most river systems, attaining lengths up to 502 mm and weights up to 1,406 g. Length-frequency histograms of roundtail chub collected in the two rivers show a disparity of juvenile fish and several "missing" year-classes. This may be a reflection of a lack of precipitation and spring runoff, which in turn appear to have an impact on reproduction and recruitment. Both radiotelemetry and PIT tagging data indicated that roundtail chub were somewhat sedentary in the lower Salt and Verde rivers during our study. The maximum distance traveled was approximately 7.5 km, but the mean distance traveled by all roundtail chub was less than 2.5 km. There was no apparent movement related to spawning events. Although we determined that the roundtail chub population in the lower Salt and Verde rivers is larger and more stable than previously reported and we collected important baseline information, more work is needed to fully understand the local life history of this unique population.

INTRODUCTION

In response to a request by the public to establish a year-round blue-ribbon rainbow trout (*Oncorhynchus mykiss*) fishery in the Salt River below Stewart Mountain Dam, Arizona Game and Fish Department (AGFD), in cooperation with the U.S. Bureau of Reclamation, began a study in 1998 to examine the feasibility of creating the unique fishing opportunity. An increase in minimum winter (October – May) discharge from Stewart Mountain Dam from as low as 8 cubic feet per second (cfs) to approximately 50-100 cfs, was proposed to increase winter survival, allow more extensive winter-time stocking, and provide additional habitat and cover for the trout. However, there was concern over the impacts of increasing flows on the unique native fish populations which occur in the lower Salt River. Impacts to native fishes in the Verde

River, a major tributary of the Salt River, were also a concern because dam operations on the Salt River directly affect dam operations on the Verde River. Therefore, the first phase of the study was an examination of the spawning and rearing habitat used by native fishes in both the lower Salt and Verde rivers (Bryan et al. 2000).

Results from the first phase of the study indicated that native fish populations in the lower Salt and Verde rivers were healthy and relatively stable. In particular, the abundance of native roundtail chub (*Gila robusta*) within the lower Salt and Verde rivers was higher than anticipated and there was evidence of successful, though minimal, reproduction (presence of larval and juvenile fish). There was also evidence that roundtail chub may move between the Salt and Verde rivers for spawning purposes.

Questions arising from results of the first year of this study led to the development of objectives aimed at learning more about the local life history of roundtail chub in the lower Salt and Verde rivers. Despite their designation as Wildlife of Special Concern in Arizona (Girmendonk and Young 1997), little is known of the status of many Arizona populations. This report summarizes information gathered during the second year of the multi-year research project and makes recommendations for areas of further study.

Specific objectives of the second year of the project conducted on the lower Salt and Verde rivers were to 1) determine the population status of adult roundtail chub; 2) track individual movements and record habitats used during spawning; 3) locate juvenile roundtail chub and determine their habitat preferences; and 4) determine species associations with regard to the roundtail chub population to identify potential competitors.

Study Area

The study was conducted in the lower Salt River, between Stewart Mountain Dam and Granite Reef Dam, and the lower Verde River, between Bartlett Dam and its confluence with the Salt River (Figure 1). Both rivers are regulated by Salt River Project and provide hydroelectric power and irrigation to the Phoenix metropolitan area. Detailed descriptions of the lower Salt and Verde rivers are provided in Bryan et al. (2000).

Methods

Population Dynamics

We sampled the lower Verde River quarterly during April - August, 1999-2000 to determine population dynamics of roundtail chub such as abundance, distribution, habitat use, and growth. The lower Salt River was only sampled during April - February, 1999-2000; high flows (> 1200 cfs) precluded sampling during spring and summer 2000. Locations that likely held roundtail chub, based on typical habitat preferences (Bestgen and Propst 1989, Ziebell and Roy 1989, Karp and Tyus 1990, Brouder et al. 2000), were identified and sampled each period using a combination of canoe electroshocking and gill netting. Up to three experimental gill nets (2.4 m x 45 m, with mesh sizes of 25.4, 38.1, 50.8, 63.5, and 76.2 mm) were set perpendicular to flow and the electroshocker was fished over the nets. When flows were too high or water was too shallow to effectively fish gill nets, only the canoe electrofisher was used.

Upon capture, roundtail chub were measured (TL, ∀1 mm), weighed (∀1 g), assessed for sexual maturity (extrusion of gametes), examined externally for general health, and scanned for an internal Passive Integrated Transponder (PIT) tag. Tag numbers of recaptured fishes were recorded; those fish without a tag were injected with one in the body cavity, posterior to the

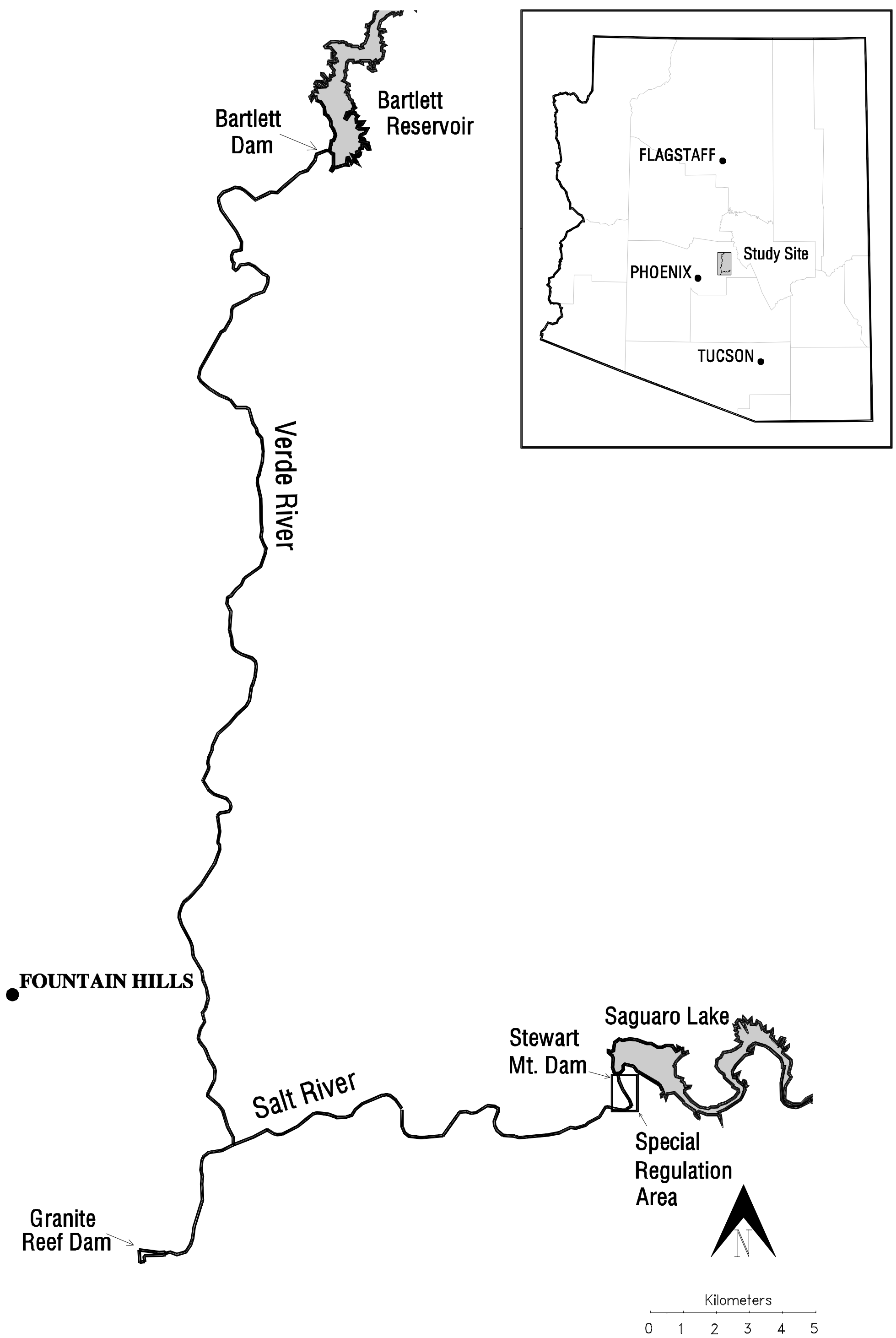


Figure 1. Map of the study area

pelvic girdle. All fish > 90 mm were injected with PIT tags. Habitat type where each fish was collected was recorded (McCain et al. 1990) and the location was mapped using GPS.

Fish could move freely between the lower Salt and Verde rivers, but both rivers are enclosed by dams, therefore, we considered all fish to be from a single population and combined data for population analysis. A Walford Line was developed to describe growth for the population based on recaptured fishes (Manzer and Taylor 1947). The line was plotted based on lengths of fish that were recaptured at least one year after the original capture date. Use of intervals shorter than one year would cause inaccurate results because of seasonal variations in growth (Ricker 1975). A length-frequency histogram was generated to evaluate the size structure of the population and identify possible gaps in year classes that may be related to environmental conditions. A distributional figure was also generated to relate occurrence of roundtail chub with topographical characteristics of the river.

The joint hypergeometric maximum likelihood estimator (JHE; Bartmann et al. 1987, White and Garrott 1990, Neal et al. 1993) was used to calculate a population estimate from mark/recapture data of PIT tagged fish. The JHE is an adaptation of the Lincoln-Petersen estimate for closed populations; estimations were calculated using NOREMARK software (G.C. White, Colorado State University, 1996). We chose to treat the population of roundtail chub as a closed population both geographically, because there was no opportunity for immigration or emigration, and demographically, because during our study there was minimal recruitment into the tagged population (Figures 6-7), and we assumed equal mortality for tagged and untagged fish (Seber 1973). Confidence intervals were determined with the profile likelihood method (Venzon and Moolgavkar 1988).

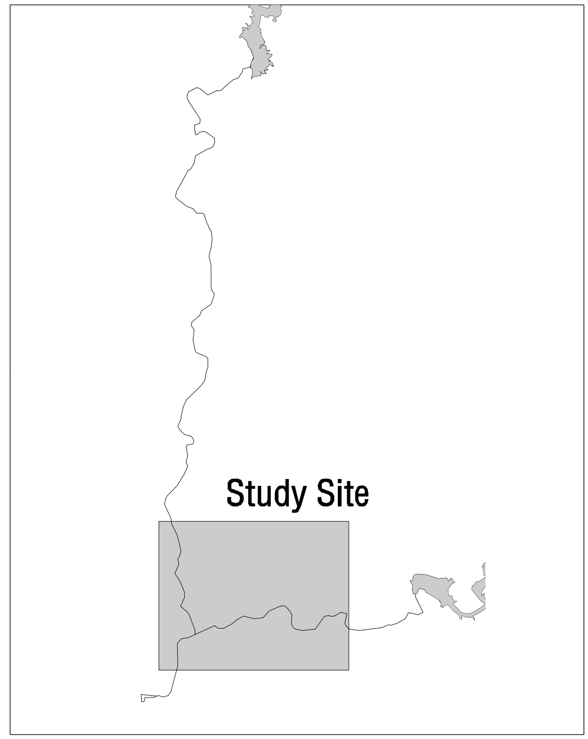
MOVEMENT

During winter (February), 20 adult roundtail chub were collected via electrofishing, anesthetized with a solution of ethanol and clove oil (Peake 1998), measured (TL, ∀1 mm) and weighed (∀1 g), and surgically implanted with a 225 day radio transmitter (15.6 g) with an external loop antennae (Advanced Telemetry Systems, Isanti, MN). Ten fish were collected in the Verde River from two distinct sites within 4 km of the Salt River confluence, and 10 fish were collected from the Salt River from three distinct sites 1-5 km upstream from the Verde River confluence (Figure 2). We concentrated our efforts near the confluence to determine if there was movement between the two rivers during spawning. Our goal was to only implant males (Winter 1996) that were over 525 g (so tags were only 3% of body weight), however, we could not capture enough large males in the study area. Therefore, we tagged 10 males and 10 females and t-tests were used to determine if there were differences in movement between the sexes. Transmitters were surgically implanted into the abdominal cavity, incisions were closed with surgical staples, and fish were released at the capture site 10 min after surgery. The surgical process lasted approximately 3 min per fish.

Fish were located from canoe and shore weekly during April (suspected time of spawning; Bryan et al. 2000) and bi-weekly during March and May-July to determine movements related to spawning. Locations of individual fish were recorded using GPS and habitat use was recorded (McCain et al. 1990). Movement was determined by measuring the distance traveled between tracking days. Upon location of the fish, we snorkeled surrounding areas to observe and record spawning behavior and habitat use.

In addition to telemetry, we used data from recaptured PIT tagged fish to assess movement of roundtail chub. Distance each recaptured fish moved was calculated based on

Release Site	Area	River	km
1	Reservation Boundary	Verde	35.7
2	Verde Rapids	Verde	37.7
3	Coon Bluff	Salt	10
4	Goldfield	Salt	11.5
5	Foxtail	Salt	15



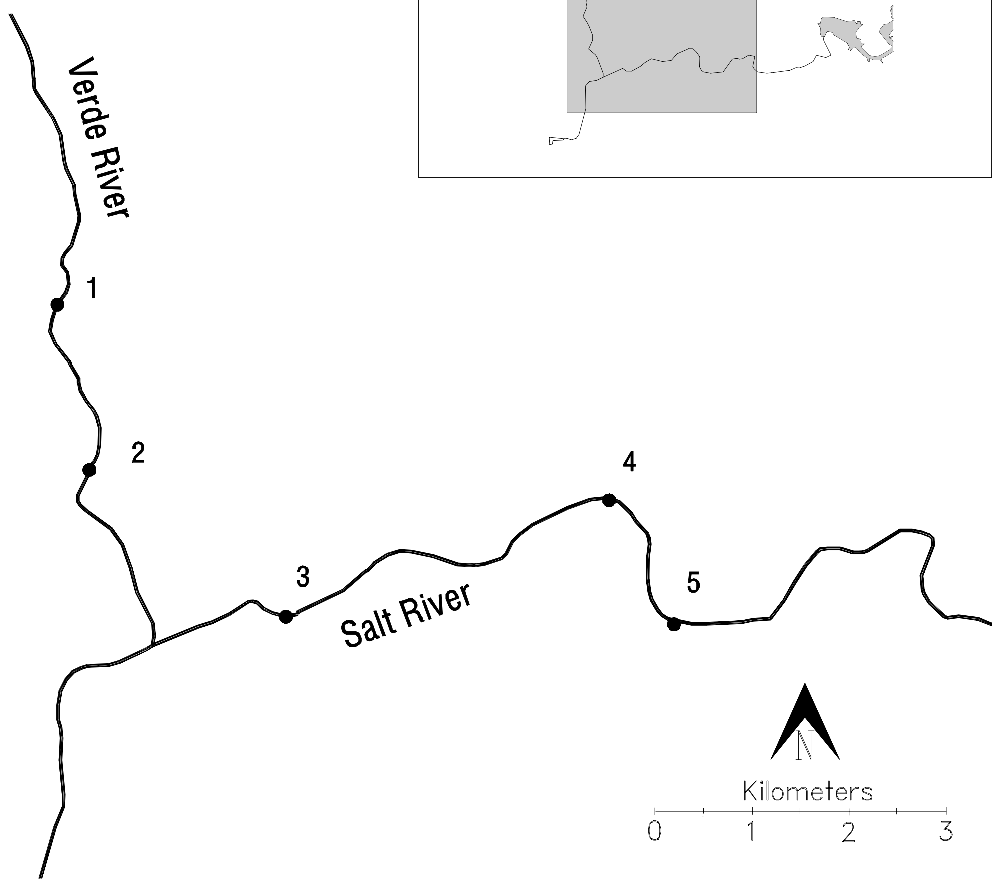


Figure 2. Map of the lower Salt and Verde rivers showing the roundtail chub movement study area and release locations. River kilometers are from Bartlett Dam on the lower Verde River and from Stewart Mountain Dam on the lower Salt River.

consecutive capture locations.

JUVENILE ROUNDTAIL CHUB

During May - August 2000, we sampled the lower Salt and Verde rivers for juvenile roundtail chub using canoe and backpack electroshocking, mini-hoop nets (see Gorman and Stone 1999), seines (6.1 x 1.8 m, 3 mm mesh), and snorkeling techniques. A specific number of sites were not pre-determined, rather we sampled various habitats reported to be used by juvenile chub (Joseph et al. 1977, Bestgen and Propst 1989, Barrett and Maughan 1995, Bryan et al. 2000) and in close proximity to populations of spawning adult fish (based on PIT tagging data). Only three juvenile roundtail chub <200 mm were collected (via canoe electrofishing), therefore we could not determine effective sampling gear, habitat preferences, or relative abundance.

SPECIES ASSOCIATION

Species associations were calculated for adult fishes collected in the same habitat type via canoe electrofishing and gill netting to identify potential predators/competitors with roundtail chub. Associations among species pairs were assessed with chi-square analysis (corrected for continuity) and the phi-2 (ϕ_2) coefficient (Zar 1984). The phi-2 coefficient ranges from -1 (species never occur together) to 1 (species always occur together), with the sign indicating either a positive or negative association. The significance of phi-2 was assessed by considering the significance of the chi-square.

RESULTS

POPULATION DYNAMICS

Roundtail chub were collected at 42 sites on the lower Verde River and six sites on the lower Salt River (Figure 3). In the lower Verde River, 908 roundtail chub were captured, of which 833 were PIT tagged; 44 of 50 chub were PIT tagged in the lower Salt River. An additional 27 roundtail chub were captured and PIT tagged in the Arizona Canal below Granite Reef Dam and subsequently released in the lower Salt River. Fish collected from canals were not included in data analyses to avoid unnecessary biases. Roundtail chub were more numerous and more closely distributed in the upper 15 km of the Verde River than in the lower reaches (Figure 4). In the Salt River, roundtail chub were sparsely distributed with a majority of the fish being collected at river kilometer 15.3 (Figure 5).

The length-frequency histograms (Figures 6 and 7) indicate there was a sizeable population of large fish (> 35 cm) in the system, but only few small fish (8 - 34 cm). Due to the low number of fish collected during autumn, 1999, length data were combined with those collected during winter 2000. Seasonal growth of the smaller fishes was easily detectable in the histograms as the cohort moved into the larger size classes over the course of the study.

When comparing fish from the two rivers, adult roundtail chub in lower Verde River had an average total length greater than those collected in the lower Salt River, but adult fish from the Salt River had a higher mean weight (Table 1). Length-weight regressions also indicate that roundtail chub from the Salt River were more robust than those from the Verde River; the regression line from roundtail chub collected in the Salt River had a slope significantly greater that of fish collected in the Verde River (ANCOVA, $P = 0.04$; Figure 8). Mean total length and weight of female roundtail chub (409.3 mm and 644.6 g, respectively) was significantly greater

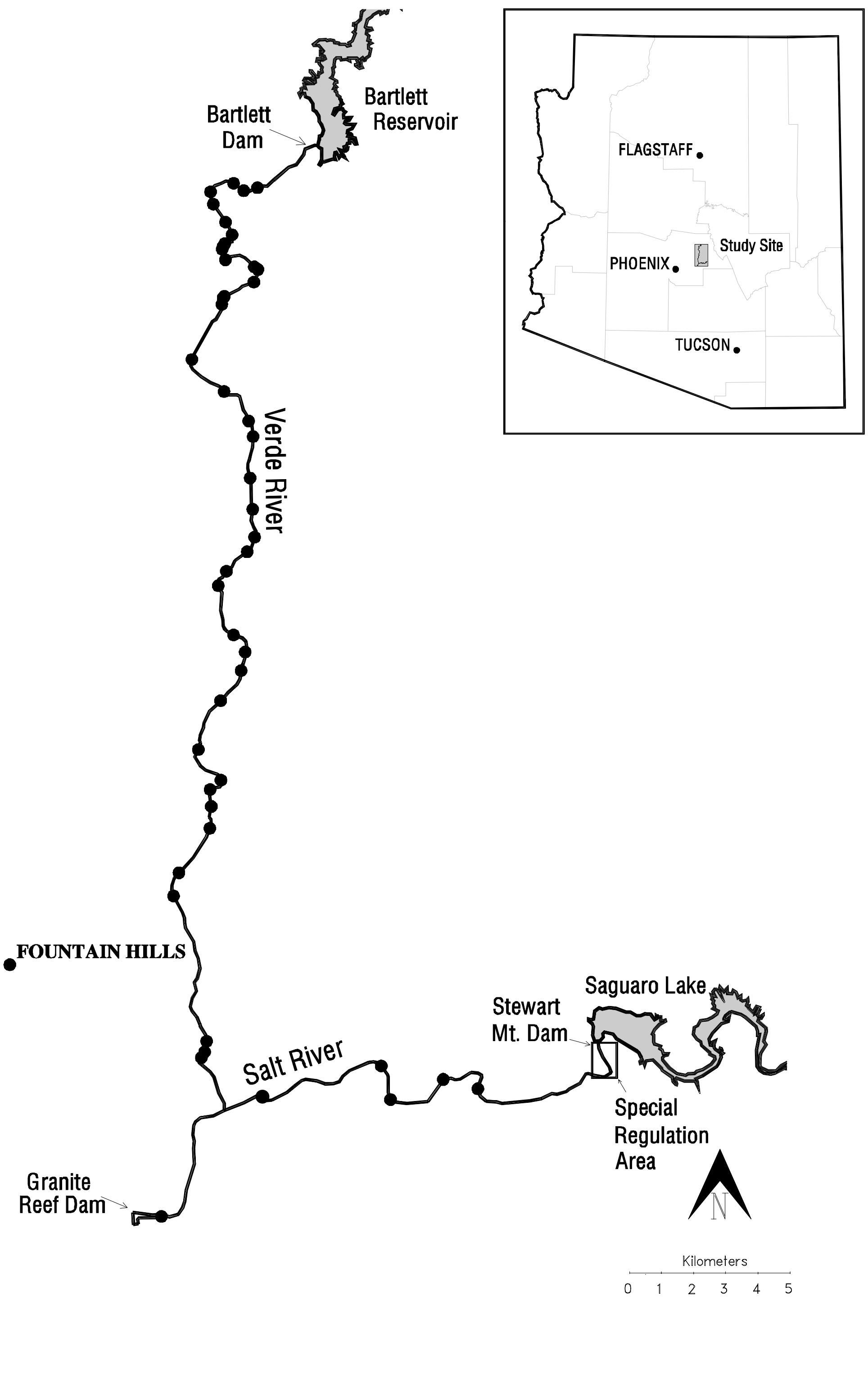


Figure 3. Locations of roundtail chub captured and PIT tagged in the lower Salt and Verde rivers, 1999-2000.

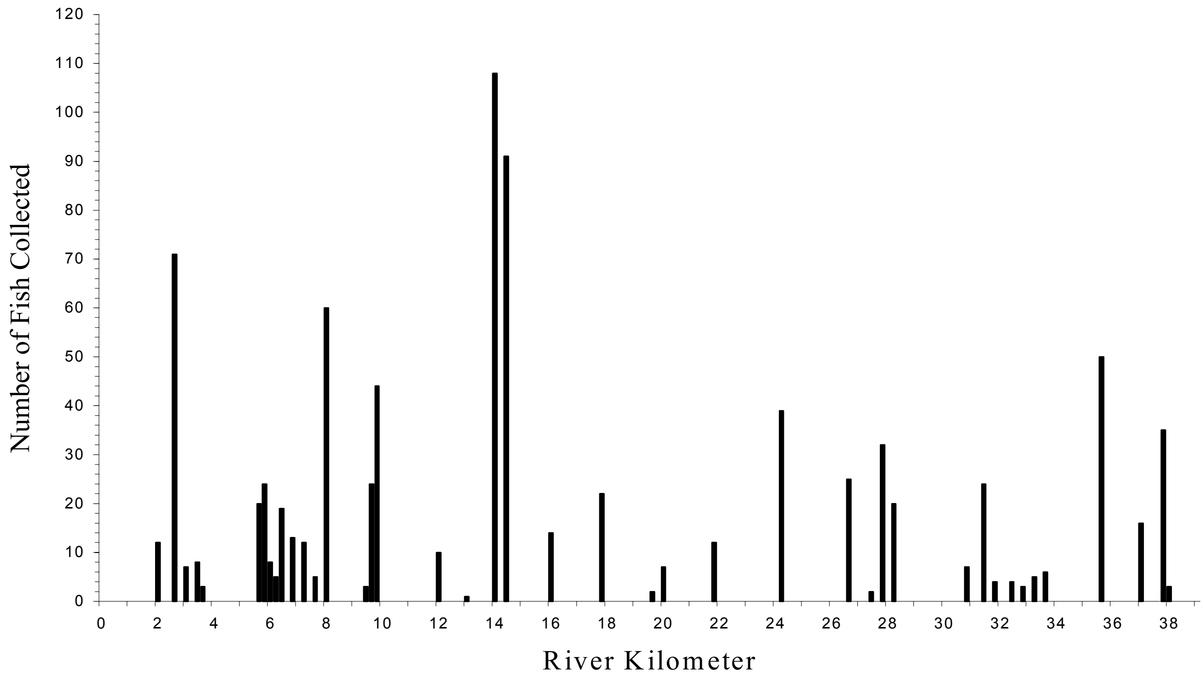


Figure 4. Distribution and abundance of roundtail chub collected in the lower Verde River, Arizona during 1999-2000. River kilometer 0 is Bartlett Dam and river kilometer 39 is the Salt River confluence.

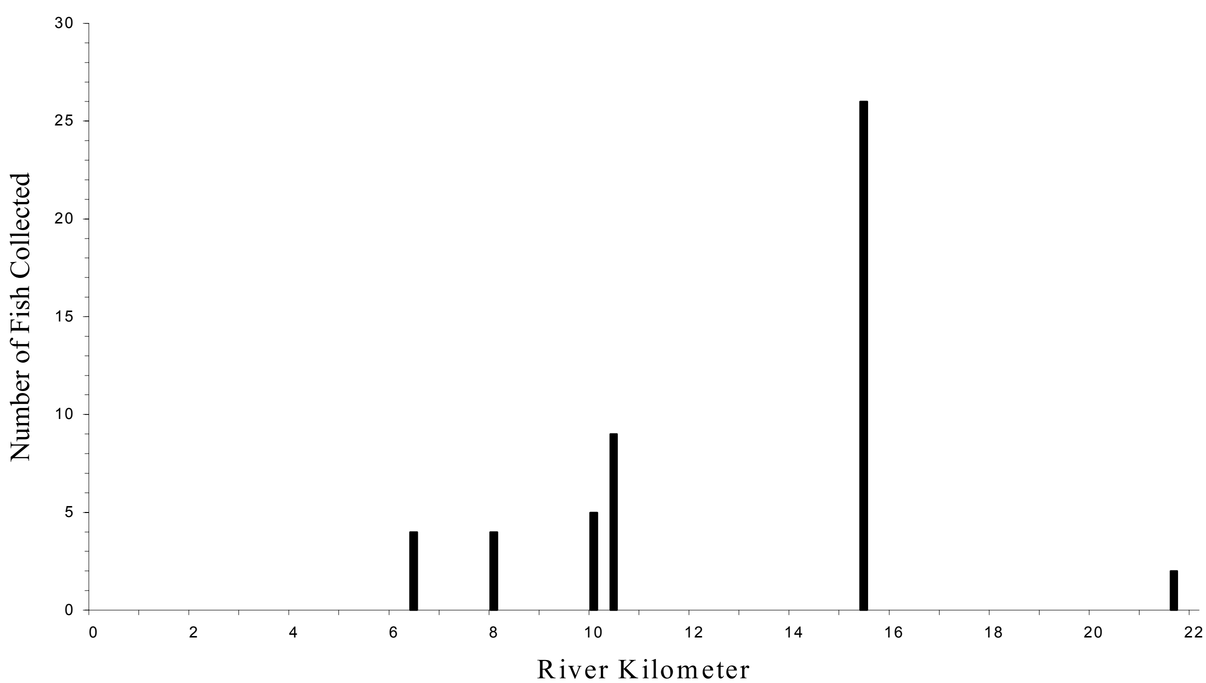


Figure 5. Distribution and abundance of roundtail chub collected from the lower Salt River, Arizona during 1999-2000. River kilometer 0 is Stewart Mountain Dam and river kilometer 22 is Granite Reef Dam.

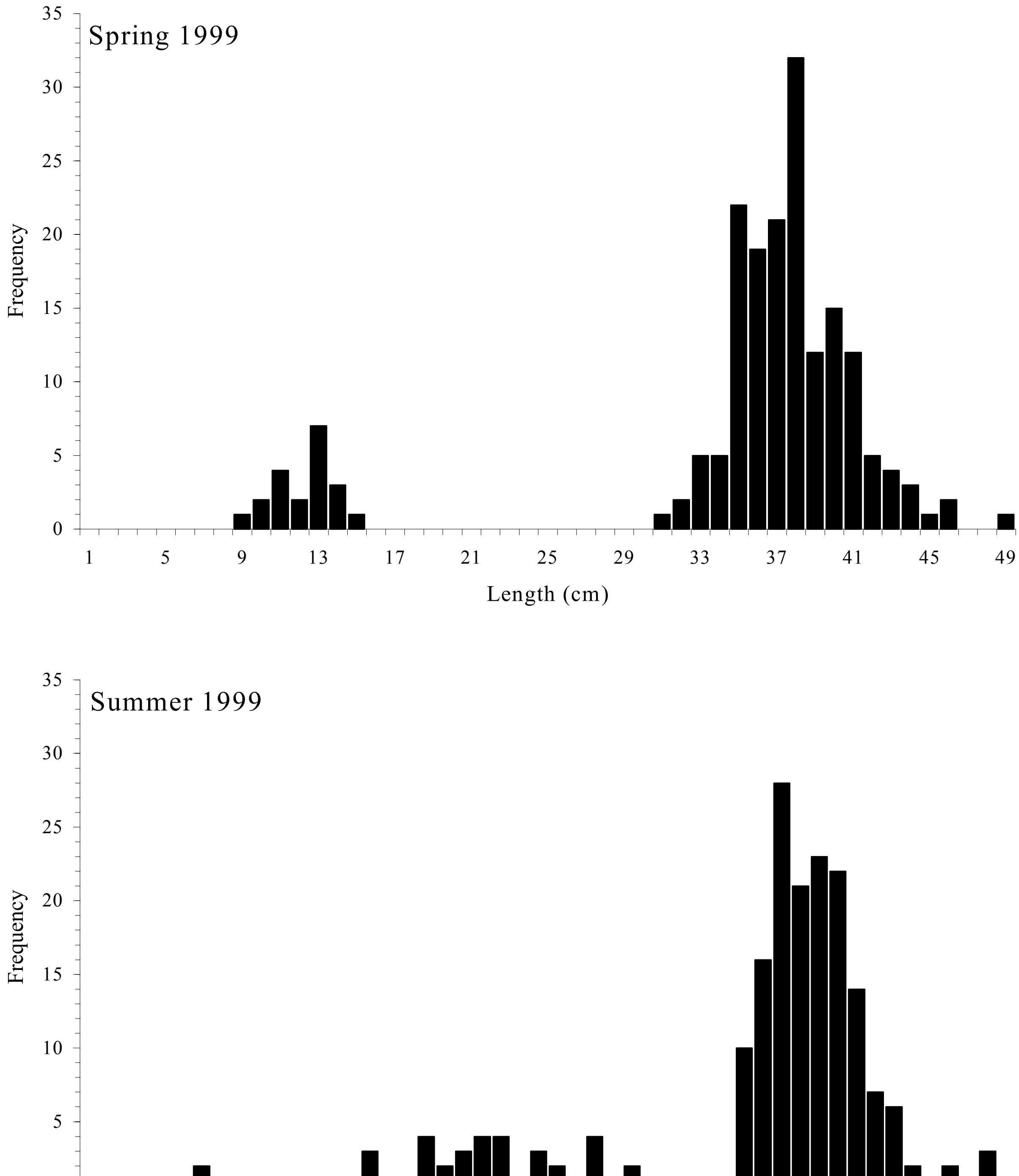


Figure 6. Length - frequency histogram of roundtail chub collected during spring and summer, 1999 in the lower Salt and Verde Rivers, Arizona.

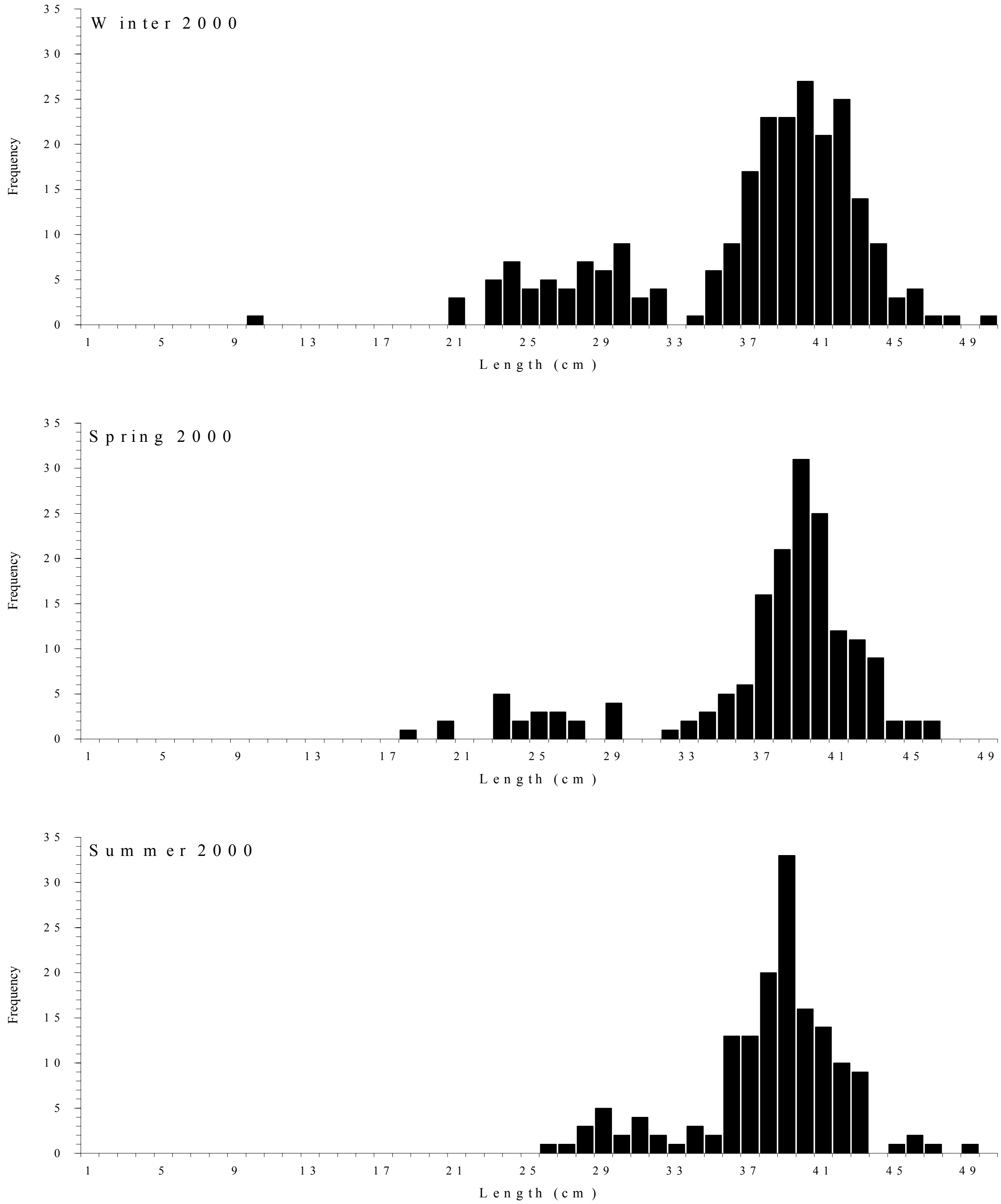


Figure 7. Length - frequency histogram of roundtail chub collected during winter, spring, and summer, 2000 in the lower Salt and Verde rivers, Arizona.

Table 1. Habitat and population characteristics of roundtail chub collected in the Salt and Verde rivers, 1999-2000. Standard deviations of means are in parentheses. Some fish were infected by more than one type of parasite.

	Salt River (n=50)			Verde River (n=908)		
	Mean (SD)	Minimum	Maximum	Mean (SD)	Minimum	Maximum
Length (mm)						
Adult (>25 cm)	377 (66)	265	502	383 (39)	251	492
Juvenile (<25 cm)	129 (98)	72	243	189 (50)	81	249
Weight (g)						
Adult (>25 cm)	601 (322)	172	1406	493 (157)	105	1206
Juvenile (<25 cm)	49 (80)	3	142	60 (42)	4	152
Habitat	Frequency	Percent		Frequency	Percent	
Pool						
Eddie	0	0		30	3.3	
Lateral Scour	4	8.0		173	19.1	
Main Channel	41	82.0		181	20.0	
Riffle						
High Gradient	0	0		31	3.4	
Low Gradient	1	2.0		137	15.0	
Glide	4	8.0		356	39.2	
Sex						
Undetermined	27	54.0		426	46.9	
Male	14	28.0		314	34.6	
Female	9	18.0		168	18.5	
Parasites						
None	27	54.0		361	39.8	
Black grub	4	8.0		2	0.2	
Yellow grub	9	18.0		79	8.7	
Lernaea cyprinacea	16	32.0		515	56.7	
Fungus	4	8.0		40	4.4	

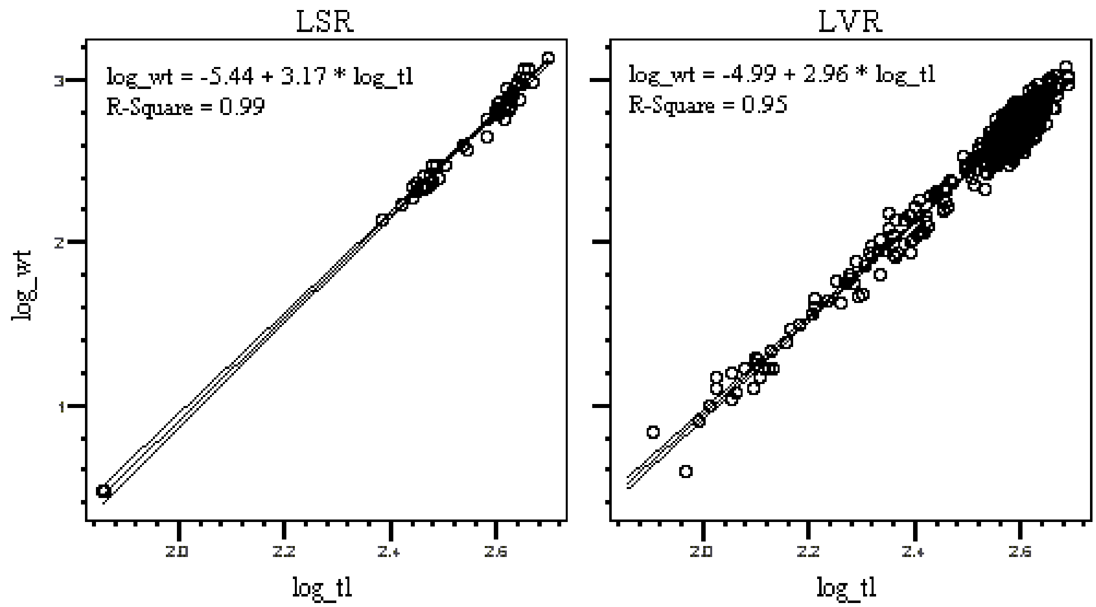


Figure 8. Length-weight regressions of roundtail chub collected in the lower Salt River (LSR) and lower Verde River (LVR), Arizona. Mean regression lines are plotted with 95% confidence intervals.

(P = 0.000 (length); P = 0.000 (weight)) than that of male roundtail chub (376.1 mm and 464.1 g). The largest roundtail chub collected was a female the measured 502 mm and weighed 1,406 g (Salt River).

A majority of roundtail chub in the lower Verde River were collected in glides, main channel pools, and lateral scour pools (Table 1). Roundtail in the lower Salt River were collected primarily in main channel pools. When sex could be determined (extrusion of gametes), males outnumbered females nearly 2 to 1. However, sex could not be determined for a majority of the fish. Roundtail chub began to show spawning colors during our winter sample (February), and by late April/early May approximately 20% of the adult chub collected were ripe (Figure 9). Few fish were in reproduction condition during fall samples. *Lernaea cyprinacea* (anchor worm) infected nearly 57% of the chub collected in the lower Verde River, while 32% of

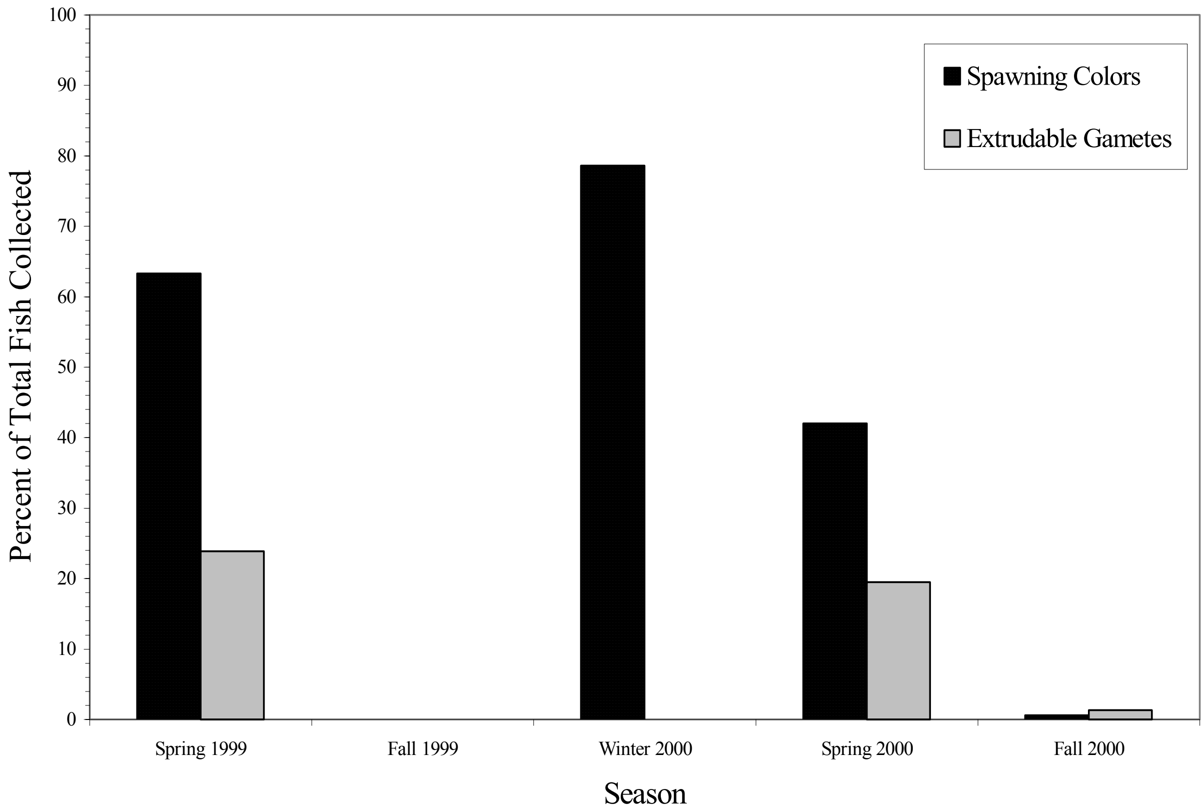


Figure 9. Frequency of roundtail chub exhibiting spawning colors (or tubercles) and extruding gametes seasonally in the lower Salt and Verde rivers.

the chub in the Salt River were infected. Yellow grub (*Clinostomum marginatum*), black grub (*Neascus*), and an unidentified fungus infected fish in both rivers.

Fifty-three of the 877 PIT tagged fish were subsequently recaptured (6%), 5 of those were recaptured on two occasions. The highest number of recaptures occurred during August 2000 sampling (20). The Lincoln-Petersen population estimate for roundtail chub in the lower Salt and Verde rivers was 6,424 individuals with a 95% confidence interval of 5,048-8,397. Mean monthly growth from PIT-tag recapture data for fish in 50 mm length (TL) groups of 250-300 mm, 300-350 mm, 350-400 mm, and >400 mm was 8.6, 1.8, 1.6, and 1.1 mm, respectively.

Growth of fish recaptured at least one year after the original capture date (n = 20) is plotted using a Walford line and its intercept with the 45° diagonal indicates an asymptotic length (L_4) of 562 mm (Figure 10). The slope (*k*) of the regression line is 0.90.

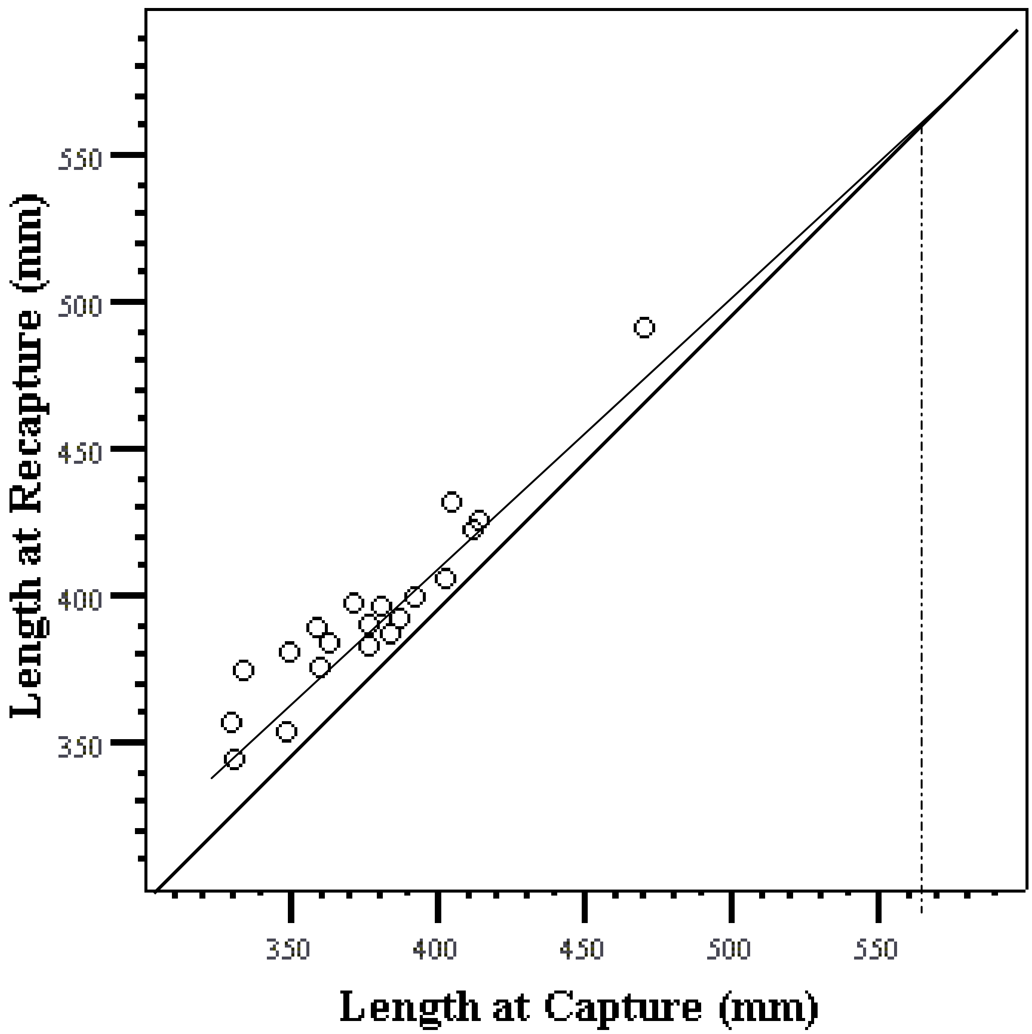


Figure 10. Length at tagging plotted against length at recapture for roundtail chub recaptured in the lower Salt and Verde rivers. The point at which the growth regression intercepts the 45° diagonal indicates an asymptotic length (L_4) of 562 mm. Slope of the regression (k) is 0.90.

MOVEMENT

Radio tagged roundtail chub were relatively sedentary during our surveys; only 10 of 20 fish moved from their original release locations over the six month study period. Seven of the 10 fish that moved had been originally released in the Verde River. There was one confirmed mortality (from unknown causes) and three suspected mortalities. Six of the 10 fish moved only once after release and two moved twice (Figures 11 and 12). Fish 40.041 and 40.121 were active throughout much of the study, moving upstream and downstream 4 and 5 times, respectively, in no apparent pattern. Two fish, 40.081 and 40.141 moved from the Verde River into the confluence area of the Verde and Salt Rivers, but otherwise there was no movement between rivers. A majority of the movement occurred during late April and early May and there was little to no movement during June and July; two individual fish moved 50 m each. The furthest movement in the Verde River was 3.5 km upstream (Table 2) and occurred just after discharge from Bartlett Dam had increased to 700 cfs from the typical 125 cfs. The furthest movement in the Salt River was 4.5 km upstream during late May, but did not appear to be related to changes in discharge. There was no difference in movements by radio-tagged male and female roundtail chub (t-test, $P = 0.06$).

Habitat use by fish implanted with radio tags was similar to that used by fish that were PIT tagged. In the Salt River, glides (44.7%) and main channel pools (36.5%) were most commonly used by roundtail chub. In the Verde River, laterals scour pools (46.8%) and glides (45.5%) were most important. In both rivers, riffles were rarely used by chub.

There was no obvious patterns in movement of PIT tagged fish; 23 recaptured fish (43.4%) did not move, 18 fish (34%) moved downstream, and 12 fish (22.6%) moved upstream. Overall mean distance traveled was 2.3 km (SD 2.2); upstream movement was 2.8 km (SD 1.9) and downstream movement was 1.5 km (SD 1.8). The longest movement was by a single fish in the Verde River that moved 7.5 km downstream between spring 1999 and spring 2000. There was no difference in movement between PIT tagged male and female roundtail chub (P = 0.346).

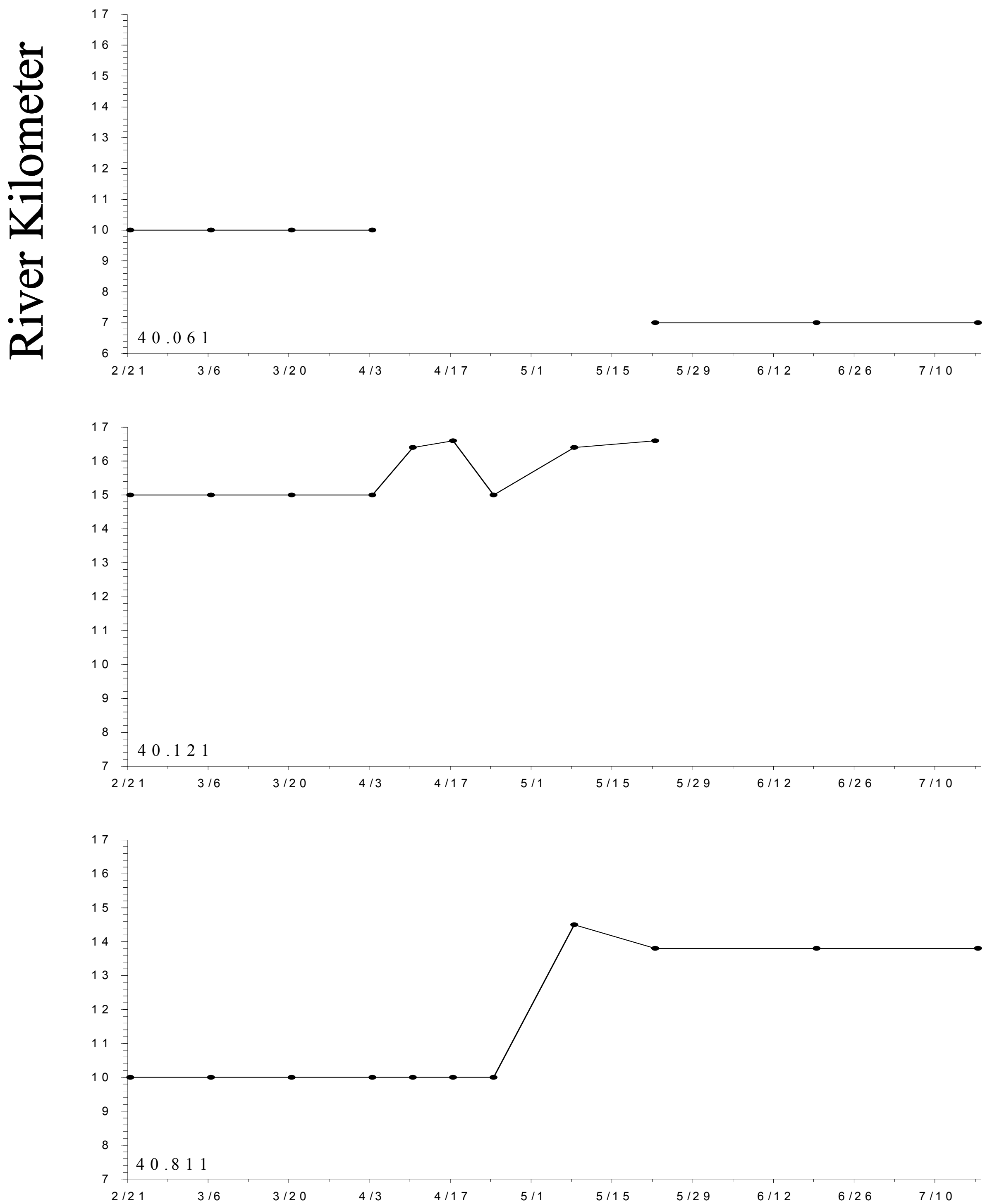


Figure 11. Movement patterns of three roundtail chub in the lower Salt River between February and July 2000. Broken lines indicate dates when fish were not located. Numbers in the lower left corner represent radio transmitter frequencies of each fish. River kilometer (RK) 0 is Stewart Mountain Dam and RK 22 is Granite Reef Dam.

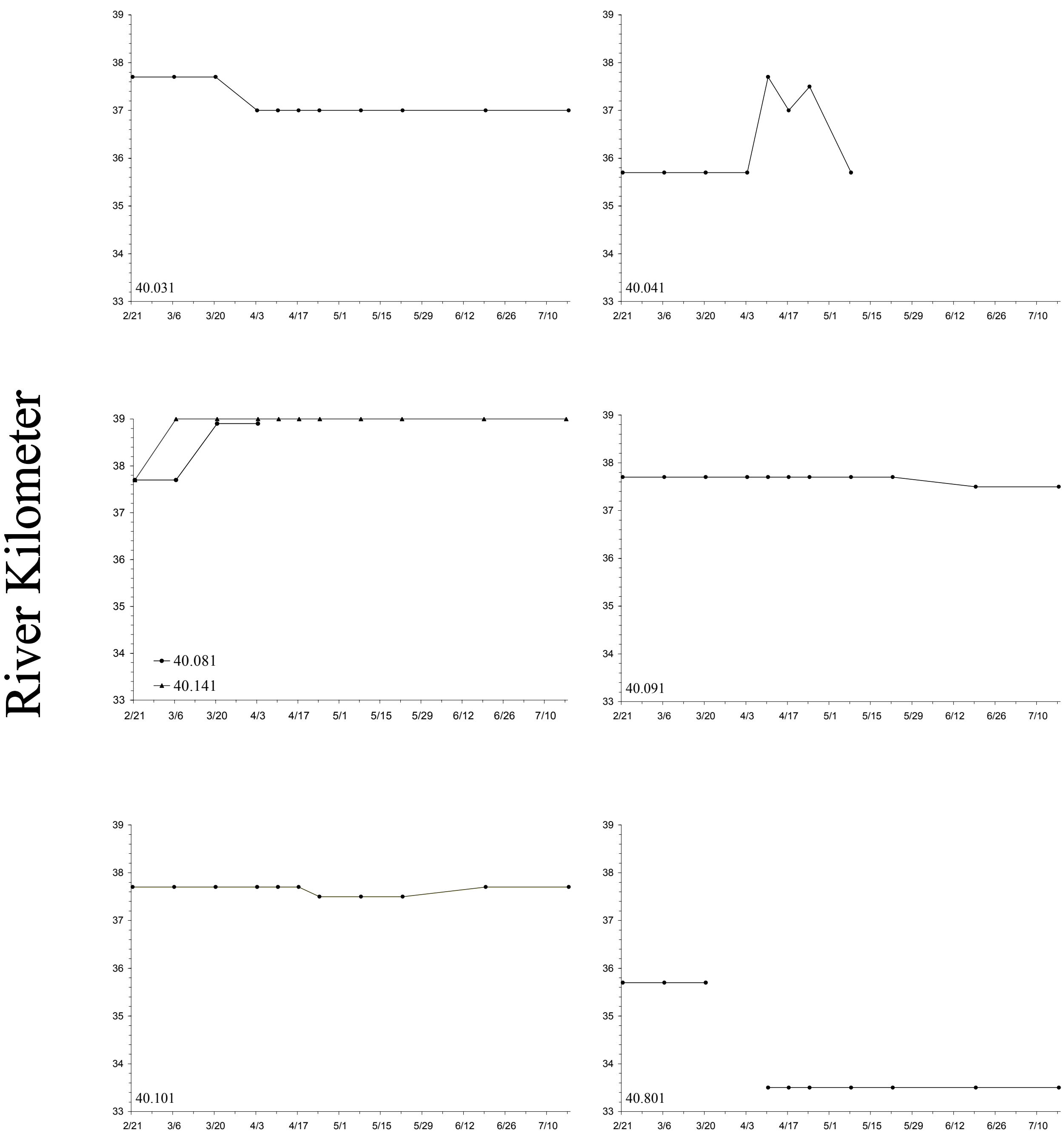


Figure 12. Movement patterns of seven roundtail chub in the lower Verde River between February and July 2000. Broken lines indicate dates when fish were not located. Numbers in the

lower left corner represent radio transmitter frequencies for each fish. River kilometer (RK) 0 is the Bartlett Dam and RK 39 is the Salt River confluence.

Table 2. Maximum distance traveled upstream and downstream by roundtail chub in the lower Salt and Verde rivers during February - July 2000. Standard deviation of means is in parentheses. (* represents confirmed mortality, ** represents suspected mortality).

	Salt River		Verde River	
Transmitter Frequency	Downstream (km)	Upstream (km)	Downstream (km)	Upstream (km)
40.011	0.0	0.0	-	-
40.020	0.0	0.0	-	-
40.031	-	-	0.0	0.7
40.041**	-	-	2.0	1.8
40.051	-	-	0.0	0.0
40.061	0.0	3.0	-	-
40.071	0.0	0.0	-	-
40.081**	-	-	1.3	0.0
40.091	-	-	0.0	0.5
40.101	-	-	0.5	0.5
40.111*	0.0	0.0	-	-
40.121	1.4	1.6	-	-
40.131**	0.0	0.0	-	-
40.141	-	-	1.3	0.0
40.151	0.0	0.0	-	-
40.801	-	-	0.0	2.2
40.811	4.5	0.7	-	-
40.821	0.0	0.0	-	-
40.831	-	-	0.0	0.0
40.841	-	-	0.0	0.0
Mean (all fish)	0.59 (1.01)	0.53 (1.44)	0.51 (0.75)	0.57 (0.80)
Mean (fish that moved)	1.97 (2.30)	1.77 (1.16)	0.73 (0.81)	0.81 (0.86)

SPECIES ASSOCIATIONS

Thirteen additional species (desert sucker *Catostomus clarki*, and Sonora sucker *Catostomus insignis*, were combined simply as catostomid species) were collected at sites where roundtail chub were located. Most associations between adult roundtail chub and other species were neutral (not significantly positive or negative; Table 3). Only the association between roundtail chub and catostomids was significant, and it was positive.

Table 3. Pairwise species associations of adult fishes in the lower Salt and Verde Rivers, 2000. Cell frequencies (number of locations) used in analysis are given: "+" indicates species presence; "-" indicates species absence. The phi-2 (N_2) coefficient (Zar 1984) ranges from -1 (species never occur together) to 1 (species always occur together), with the sign indicating either a positive or negative association. Statistically significant (* = P < 0.05) chi square (corrected for continuity) indicates significant phi-2.

Species		Cell frequencies					
A	B	A(-) B(-)	A(-) B(+)	A(+) B(-)	A(+) B(+)	N_2	Π^2
	Yellow Bullhead	13	1	41	2	-0.05	0.13
	Sucker species	8	6	4	39	0.51	14.54*
	Common Carp	13	1	35	8	0.17	1.72
	Red Shiner	8	6	16	27	0.14	1.04
	Channel Catfish	10	4	20	23	0.21	2.63
	Green Sunfish	13	1	35	8	0.14	1.04
Roundtail Chub	Bluegill	14	0	41	2	0.11	0.67
	Smallmouth Bass	14	0	42	1	0.08	0.33
	Largemouth Bass	5	9	6	37	0.24	3.21
	Yellow Bass	14	0	42	1	0.08	0.33
	Rainbow Trout	14	0	39	4	0.16	1.40
	Flathead Catfish	13	1	29	14	0.25	3.52
	Tilapia	11	3	39	4	-0.16	1.44

DISCUSSION

Except for a few angler accounts, AGFD had no prior collection record of roundtail chub inhabiting the lower Verde River below Bartlett Dam (Girmendonk and Young 1997). However, other studies (Minckley 1985, Hunt et al. 1992) have indicated that a small population of roundtail chub inhabits reaches on the lower Verde River. Similarly, very few roundtail chub have been reported in the lower Salt River below Stewart Mountain Dam (Hunt et al. 1992, Clarkson 1998). Contrary to these findings, we found roundtail chub in both rivers and the estimated population size of chub inhabiting the two rivers is greater than found in the upper

Verde River (Brouder et al. 2000) and most other locations in Arizona (Girmendonk and Young 1997). Although our population estimate was not generated from a random sample of fishes taken in the two rivers, our fixed sites were scattered throughout both rivers, so we believe it to be an accurate estimate for the entire system. Also, despite the relatively large population, the absence of juvenile fish and low number of larval fish (Bryan et al. 2000) in our collections may be an indication that the population is unstable and recruitment is limited or sporadic.

Roundtail chub were most prevalent in the upper reaches of the lower Verde River where the stream gradient was high and the river was bound by canyon walls. The topography of the upper portion of the river resulted in the presence of numerous pool-glide complexes that were adjacent to swift moving riffles. These are habitats preferred by adult roundtail chub (Ziebell and Roy 1989, Karp and Tyus 1990, Rinne and Minckley 1991). The downstream portion of the lower Verde River became wider and shallower with a moderate gradient, which resulted in a smaller proportion of preferred habitats and thus lower abundance of roundtail chub.

In the Salt River, low flows (~ 8 cfs) during winter confined roundtail chub to deep pools. Although movement of these fish was restricted because of the reduced discharge, they proved difficult to capture using electrofishing and gill nets, probably due to high conductivity (~1350 :S/cm). We snorkeled sites just after sampling with the electrofisher and determined that we were only collecting approximately 10% of the roundtail at that site. High flows during spring and summer added to our difficulty in capturing fishes in the Salt River, so our perception of chub distribution and abundance may be biased due to the constraints of our sampling gear and methodology.

Length-frequency distributions can aid in identifying problems such as year-class failures or low recruitment, slow growth, or excessive annual mortality (Anderson and Neumann 1996).

During spring 1999, we collected a small number of juvenile fish that eventually grew into the adult population, however, the length-frequency histograms of roundtail chub collected in the two rivers clearly shows a disparity of young fish and probably at least three missing year-classes. This lends further evidence to the hypothesis that for many native fish, including roundtail chub, spawning and subsequent recruitment is based on the occurrence of significant flood events (Poff and Allan 1995, Rinne and Stefferud 1996, Brouder *in press*). Since 1995, the area has only been subjected to a flood event during early April 1998, which is reflected by the juvenile fish collected during spring 1999. Brouder et al. (2000) saw similar reproduction and recruitment in the upper Verde River during the same time period. The apparent absence of other year classes of roundtail chub may be a direct reflection of a lack of precipitation and spring runoff.

Although there was limited data available, growth of roundtail chub in the lower Salt and Verde rivers was very similar to chub in the upper Verde River (Brouder et al. 2000), however, fish in our study attained much larger sizes than those in the upper Verde River. This is also reflected by the Walford line that was created from growth of recaptured fish, which estimated an asymptotic length of 562 mm. Mark-recapture data from roundtail chub collected in the upper Verde River provided an estimated 525 mm asymptotic length (unpublished data). In fact, roundtail chub collected in the lower Salt and Verde rivers achieved greater lengths than reported in most studies (Vanicek and Kramer 1969, Neve 1976, Ziebell and Roy 1989). This may be due to factors such as water temperature, food availability, or habitat. The Walford line also allows for calculation of Ford's growth coeffecient ($k = 0.9$), and together with asymptotic length (L_4), gives us the ability to predict growth of individual fish in the lower Salt and Verde rivers (Ricker 1975).

Roundtail chub in the lower Salt River were also more robust than those collected in the lower Verde River, but very similar to other rivers (Vanicek and Kramer 1969, Brouder et al. 2000). The slope of the regression lines for chub in both rivers was nearly equal to 3.0, which represents isometric growth (shape does not change as the fish grows; Anderson and Neumann 1996). Girmendonk and Young (1997) pointed towards parasitic infestation as a factor that could potentially hinder growth. Nearly 60% of chub in the lower Salt and Verde rivers were infected with some type of parasite (especially *Lernaea*), but growth rates were greater than or consistent with those reported in these other studies. Infestation of *Lernaea* was more prevalent in the lower Verde River than in the lower Salt River and could be a factor in the difference in size structure of fishes in the two rivers.

Both radiotelemetry and PIT tagging data indicated that roundtail chub are somewhat sedentary in the lower Salt and Verde rivers. Kaeding et al. (1990) found that roundtail chub implanted with radio tags moved extensively (up to 34 km) in a large river and that the movement was related to spawning events. Conversely, Siebert (1980) and Brouder et al. (2000) found that roundtail chub move very little in small Arizona streams. Roundtail chub in the lower Verde River behaved similarly to those found in small streams, which may be reflective of the constant, relatively low flows (< 150 cfs) present during our study. The only large movement by chub in the Verde River was observed just after a significant short-term spike in the discharge (from 125 cfs to 700 cfs over a 72 h period). In the Salt River, we only recorded one instance of a long distance movement and that also occurred just after a large spike in dam discharge (from 400 cfs to 1,200 cfs), however high flows were available for much of study period in the Salt River. The lack of significant movement in the lower Salt River may be attributed to abundant food sources, habitat, or simply no spawning migration due to drought conditions. It is possible that roundtail chub move during night, especially for feeding and thus we could not detect movement during daytime. Also, the six month period in which we radio-tracked roundtail chub may not have been long enough or during the right time of year to detect large scale movement.

Contrary to our previous hypothesis that chub move between rivers for spawning purposes (Bryan et al. 2000), no fish moved from the Salt River to the Verde River during our radiotelemetry study. Although spawning habitat appears to be more suitable in the lower Verde River (Neve 1976, Ziebell and Roy 1989) fish remained relatively close to their release locations during the suspected time of spawning (April-May; Vanicek and Kramer 1969, Kaeding et al. 1990, Bryan et al. 2000). We also did not observe spawning behavior during our study, although fish showed spawning coloration (Bestgen 1985, Muth et al. 1985) and were readily expressing gametes throughout much of the spring. The absence of spawning migration (Kaeding et al. 1990) and lack of spawning behavior may be related to discharge and temperature, which may not have been suitable for roundtail chub spawning during 2000 (Bestgen 1985, Kaeding et al. 1990, Bryan et al. 2000). Studies have suggested that implanting tags into mature fish can potentially adversely affect physiology and behavior (Burger et al. 1985, Marty and Summerfelt 1986, Greenstreet and Morgan 1989, Winter 1996). However, we observed roundtail chub on numerous occasions while snorkeling and there appeared to be no difference in behavior of tagged and untagged fish.

Roundtail chub tended to co-occur with the two sucker species, desert and Sonora sucker, but not with other species. This is not surprising as both suckers species are prevalent throughout both rivers. If data from the Verde river were broken into an upper and lower reach, we may see significant positive associations between some of the nonnative fishes and roundtail chub due to the prevalence of exotics in the lower reaches. Also, because our gear does not select for adults of small species (i.e. red shiner and mosquitofish), our results may not reflect potential significant associations between roundtail chub and some of these smaller species. The association among these species may be important as red shiner and mosquitofish have been shown to prey on and compete with early life stages of other fishes (Greger and Deacon 1988, Meffe et al.1983).

FURTHER RESEARCH NEEDS

Roundtail chub are one of the more unique native fishes in Arizona; they are currently a sportfish and a Species of Special Concern. As such, it is vital that we continue to monitor populations of roundtail chub to learn more about the mechanisms which influence reproduction and survival. Although we determined that the roundtail chub population in the lower Salt and Verde rivers is larger than previously reported (Girmendonk and Young 1997) and we collected important baseline information on this unique population, the two-year study was not sufficient to determine population stability. It appears that flood events and in this case, dam discharge, play a significant role in the reproductive success of the chub, but those conditions did not exist during the course of this study. Therefore, we did not observe spawning behavior, spawning migrations, or recruitment into the adult population and we were not able to assess factors which contribute to spawning success. However, because there is still a large number of fish in the two rivers that are PIT tagged, there remains a relatively inexpensive opportunity to continue to monitor the population over the next several years.

The ultimate question remains as to how increased winter discharge and the addition of large rainbow trout to the Salt River will affect native fish populations. Based on our two-year study, we suggest that water flows may play an important role in the life history of roundtail chub (as well as other native and nonnative fishes), but increases in winter flows of only 50 cfs will likely not have an impact on the chub population (Bryan et al. 2000). The potential competitive interaction between large rainbow trout and roundtail chub appears to be the factor that could most severely affect the roundtail chub population, however, further research is needed to adequately assess the degree of that competitive impact.

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